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Keynote Lecture

DAMAGE, LOSSES, RECONSTRUCTION POLICIES, AND RETROFIT INTERVENTIONS ON RESIDENTIAL BUILDINGS IN HISTORICAL CENTERS AFTER RECENT ITALIAN EARTHQUAKES

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1. Abstract

The reconstruction process of residential buildings damaged by L'Aquila 2009 earthquake initially involved buildings outside historical centres and then, starting from August 2012, residential buildings in historical centres. The reconstruction model related to buildings in historical centres was developed by two special offices, involved in the reconstruction process of L'Aquila municipality and other municipalities, respectively. Both special offices introduced new procedures to manage the reconstruction based on a parametric model to define the maximum public grant to repair and strengthen the damaged buildings in historical centres. The new model was necessary to deal with the reconstruction of historical centres mainly characterized by old masonry building aggregates with a cultural and architectural heritage value. The data collected in the management process of reconstruction outside and inside historical centers, allowed obtaining precious and unique information on buildings and aggregates characteristics, damage and usability ratings as well as repair and retrofitting cost data obtained by funding requests. Furthermore, these data are the basis to carry out a comparison between the repair and retrofit cost data and peculiarities of residential buildings outside and inside historical centers.

2. Reconstruction process of residential buildings inside and outside historical centers

Two different phases can be clearly distinguished in the reconstruction process after the L'Aquila earthquake. A first phase involved the reconstruction of residential buildings outside historical centres (OHC); the reconstruction policy was regulated by Law 77/2009 and several Ordinances of the President of the Council of Ministers (OPCM). At this stage the financial strategy of the Italian government was to fully cover the repair work costs to restore the usability of damaged buildings; furthermore, different thresholds were defined for strengthening interventions as a function of the usability rating of each building. The usability rating was determined by proper post earthquake field inspections carried out by team of surveyors; the AeDES survey form (Baggio et al. 2007) was adopted as a tool for the seismic damage and usability assessment. According to the AeDES survey form, the buildings can be classified into the following categories: A. Usable buildings (slightly damaged, can keep on housing the functions to which it was dedicated); B. Building usable only after short term countermeasures (buildings with limited or no structural damage but with severe non-structural damage); C. Partially usable building (build-ings with limited or no structural damage but with severe non-structural damage located in a part of the building); D. Building to be re-inspected (due to atypical damage scenario a specific, but still visual, investigation is required); E. Unusable building (high structural or non-structural risk, high external or geotechnical risk); F. Unusable building for external risk only.

For each building the repair and strengthening works and relevant costs were determined by practitioners engaged by owners. A proper team, called "Filiera" was set up to oversee these projects from the administrative, technical and economic angle and to deal with the numerous applications for

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funding. At the end of this reconstruction phase, funding applications related to 5,775 residential buildings outside the historical centre of L'Aquila and other municipalities were examined and approved by the Filiera. The total amount allocated residential buildings outside the historical centre of L'Aquila municipality allocated until September 2013 was about 2,1 billion and the total amount due to the activity of the Filiera can be estimated of the order of 2.6 billion euros. Details about this first phase of the reconstruction process can be found in Di Ludovico et al. 2016a,b.

The second phase of the reconstruction process involved buildings inside historical centres (IHC) of L'Aquila and other municipalities; the reconstruction policy was regulated by Law 134/2012, which introduces a parametric model to determine the maximum public grant eligible to restore the usability of damaged buildings. The financial strategy of the Italian government was to fully cover not only the repair and strengthening costs to restore the usability of damaged buildings but also to establish some extra public funds to preserve the cultural and architectural heritage value of these buildings.

A new reconstruction model defined on the basis of new procedures was necessary in order to deal with the reconstruction of old masonry building aggregates (i.e. groups of masonry buildings to form complex building agglomerates) with a cultural and architectural heritage value. In this case, the reconstruction model refers to: a) Building Aggregates (namely BA); b) a portion of the BA with homogeneous characteristics, Aggregate Minimum Unit (namely AMU), see Figure 1 (e.g. the aggregate depicted in such figure is analysed by means of two applications related to AMU).The application for funding related to BA or AMU contains data related to one or more buildings (B) which consist of one or more dwellings.

Historical masonry buildings incorporate structural elements, such as arches, domes, vaults and irregular shaped-columns, with earthquake-response, which is difficult to simulate and predict in numerical analyses; furthermore, the seismic retrofitting measures in these cases are not straightforward because they should encompass efficiency and safety, compatibility with existing materials, non-invasive scheme and reversibility, as well as durability of the intervention. The built heritage conservation requires to apply minimally invasive techniques, but capable to ensure a significant increase of seismic safety. Operating on such a context involves a high level of un-certainty to define the state of preservation of structural and non-structural elements. It is particularly difficult to predict the exact amount of works to be performed during the design phase, therefore implementing a procedure capable of guaranteeing work in progress variants with an agile tool becomes essential, also ensuring expenditure control in the meantime.

Figure 1. Building Aggregate and sub-units.

Given the complex spatial and morphological structure of the territory, special rules for reconstruction have been issued for historical centres. The management of such stage of the reconstruction process was assigned to two special offices: the Special Reconstruction Office of L'Aquila - USRA - for the

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reconstruction process of buildings in historical centres of L'Aquila, and the Special Reconstruction Office of the Crater Municipalities - USRC - for the reconstruction process of buildings in historical centres of other municipalities (56 municipalities in the area hit by the earthquake, the so called "crater").

To date the reconstruction process of IHC residential buildings is still ongoing. Details about this phase of the reconstruction process can be found in a "white book", published within the framework of the PE2019–2021 joint program DPC-ReLUIS, WP7: "Post-earthquake data analysis", consisting of seven chapters dealing with different aspects (Di Ludovico at al. 2022): *i)* Reconstruction procedures for residential buildings damaged by L'Aquila 2009 earthquake; *ii)* The reconstruction process inside the historical centers; iii) Characteristicts of building stock in the historical centers; iv) Damage on buildings in the historical centers; v) Repair and retrofit interventions; vi) Cost analysis; vii) Comparative analysis between repair costs for the reconstruction inside and outside the historical centers. The book reports data related to funding requests for repair and strengthening interventions on 1,421 BAs, 1,595 AMUs and 6,198 Bs. They corresponds to total amount of about 3,0 billion euros.

Details about number of buildings per AMU and their total gross surface as well number of storey and total gross surface of Bs are reported in Figure 2; it clearly appears that in most cases (56%) AMU consists of three of less buildings and have an average surface of 1,343 m^2 while buildings are commonly made by two or three storeys with an average surface of about 294 m^2

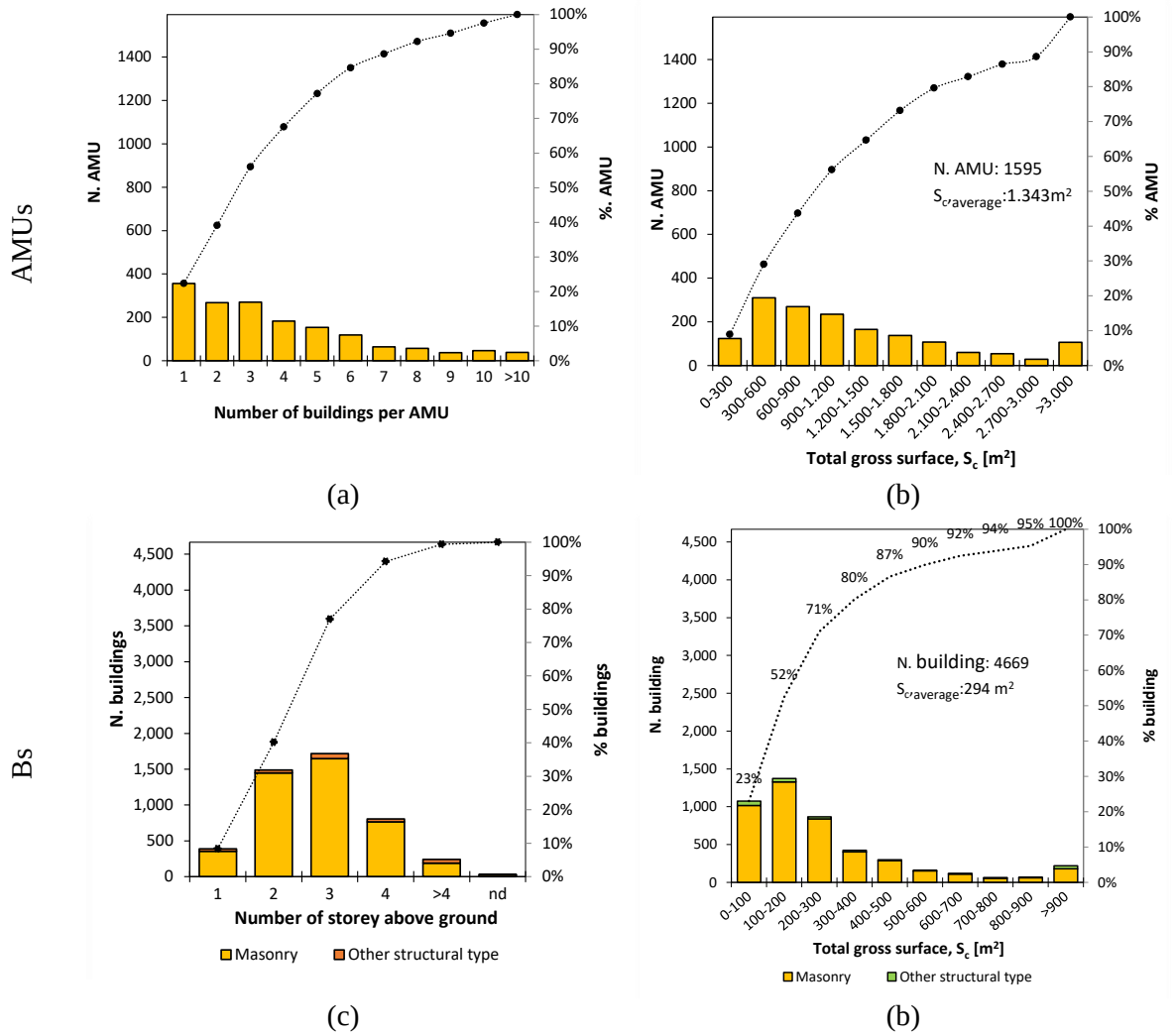

Figure 2. AMUs and Bs characteristics.

The data reported in the study shows that damage suffered by the buildings located in the historical centers may significantly differ from that detected on isolated buildings outside the historical centers;

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furthermore, for building aggregates, edge and corner buildings are more vulnerable than the internal ones. The cost analysis carried out on both OHC and IHC building stock, showed that significant extra costs need to be accounted in the reconstruction process to preserve, restore and mitigate the seismic risk of historic-architectural valuable elements, buildings with landscape interest or buildings of cultural interest

The data collected by the Government Institutions involved in the 2009 post-earthquake reconstruction, both for OHC and IHC reconstruction process, provides an important database for future analyses and promote the definition of a unique code defining basic principles and rules for reconstruction. Furthermore, they are a precious for the calibration and refinement of models aiming at the evaluation of the seismic risk at large scale (Dolce et al. 2020, Di Ludovico et al .2022).

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